PBFA II, A 100 TW PULSED POWER DRIVER FOR THE INERTIAL CONFINEMENT FUSION PROGRAM*

B. N. Turman, T. H. Martin, E. L. Neau, D. R. Humphreys, D. D. Bloomquist,
D. L. Cook, S. A. Goldstein, L. X Schneider, D. H. McDaniel, J. M. Wilson,
R. A. Hamil, G. W. Barr, and J. P. VanDevender
Sandia National Laboratories
Albuquerque, NM, 87185

Abstract

The 100 TW Particle Beam Fusion Accelerator (PBFA II) is well into the procurement and assembly phases, with the first shot scheduled for January 1986. Installation of several major sub-assemblies is underway. The PBFA II output will drive a fast opening switch in the vacuum insulator stack, providing a 30 MV, 15 ns output pulse,which accelerates lithium ions. The ions will focus onto a pellet containing deuterium-tritium, producing fusion energy. Several research areas will be reviewed: low jitter, highly reliable 370 kJ Marx generators; highly synchronized gas switching at 5 MV; efficient water switch operation of 5 MV lines; series-parallel arrangements for increasing voltage or current; and plasma erosion opening switches.

I. Introduction

Sandia National Laboratories' Particle Beam Fusion Program is dedicated to the quest for fusion power through inertial confinement.[1] This program began in the early 70's with the goal of developing intense electron beams to compress D-T fuel pellets, causing nuclear ignition. Computer simulations of the D-T pellet implosion process suggested that the range of interest for successful fuel ignition lay somewhere around 1-10 MJ and 50-200 TW/cm^2. These energy and power levels were not attainable at the time, but were nonetheless within the range of future technology. By the late 70's experimental and analytical studies showed that light ion beams offered more promise for efficiently driving the D-T pellets. Based on this information, the Electron Beam Particle Accelerator was converted to a light ion beam accelerator, renamed "PBFA I", and given the more generic mission of accelerating particles. The 30 TW PBFA I was commissioned in June 1980, and the first ion diode experiments began in May, 1981.

The potential advantage of pulsed power using light ion beams is the relatively high energy efficiency. A 20% efficiency is obtainable with proper impedance matching of the diode to the accelerator. The major disadvantage, however, is the inherent difficulty of focussing a charged particle beam onto a small target. The primary objective for PBFA I has been to develop ion diodes that demonstrate the potential for focussing high voltage, high current ion beams. Recent results inspire confidence that the ion focussing problem may be solvable.[2] Proton beams on PBFA I have been focused to a power level of 1.5 TW/cm^2 with a beam divergence of a mere 14 milliradians. This divergence and power level are consistent with scaling relations developed from earlier ion focussing experiments.

PBFA I was not designed to deliver sufficient power or energy for ignition, but was intended as a stepping stone to the next generation machine, PBFA II. Design work on PBFA II began immediately upon completion of its predecessor. The goal of exploring the energy and power regions for ignition challenged PBFA II. The pulsed power design of this machine evolved from the technology used on PBFA I, building on previous experience and striving for maximum output energy, voltage, and power. Based on scaling of the PBFA I focussing data, a 30 MV lithium ion beam should give a focused beam intensity of over 100 TW/cm^2. If that intensity can be achieved, and there are many reasons for optimism at this point, then PBFA II may well be the machine that achieves nuclear ignition in the laboratory for the first time.

II. The PBFA II Project

The original plan for PBFA II called for a simple upgrade of PBFA I after two years of its operation. This upgrade would add 36 more modules to the existing PBFA I, doubling the available energy. PBFA I operations began, and several flaws in this plan became apparent: (1) A higher voltage machine, designed specifically for ions, was needed; (2) this plan required shutting down PBFA I during the upgrade period, thus halting vital ion focussing experiments; (3) the important parameter range for fusion investigations was more than a factor of 2 beyond PBFA I, requiring an upgrade of a factor of 4; and (4) machine synchronization was vital for power transport and beam focussing. With 36 modules, PBFA I was plagued with excessive timing spread, and this situation would only worsen with the addition of more modules. Thus, a new PBFA II construction project, with the goals of building an independent accelerator to deliver 3.5 MJ, at more than 100 TW, to a high voltage (ultimately decided 30 MV) ion diode, was conceived in 1981. The first full accelerator shot is expected in January 1986. The current completion cost estimate is $48 M.

The technical approach followed in this project can be summarized in five design philosophies.

1. Develop improvements over the proven technology of PBFA I. The Marx generator illustrates this point. The PBFA II Marx will store four times the energy of the PBFA I Marx. This increased capability was obtained by using 1.35 microfarad capacitors, rather than 0.7 microfarad capacitors of PBFA I, and increasing the number of capacitors from 32 to 60. The electrical design grew out of the extensive testing base from operational experience with PBFA I. The timing jitter of the new Marx has been significantly reduced as a result of better understanding of the erection process. The culmination is an improved design which has four times the energy, one-third the timing jitter, and increased reliability over its predecessor.
2. Continue a strong research program to develop the latest technological advances in areas where large performance improvements are necessary, while maintaining research in parallel with engineering design to meet stringent project delivery schedules. The plasma erosion opening switch is an example. The final power compression stage must be in vacuum, near the input of the ion diode and provide a factor of two in power gain. This compression stage will be provided with a plasma erosion switch. Because this is such new technology, particularly at the higher voltage levels of PBFA II, the design of this switch is evolving as new experiments are conducted on PBFA I as well as the Naval Research Laboratory. Research will continue as PBFA II comes into operation.

*This work supported by the United States Department of Energy under Contract Number DE-AC04-DP00789.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 1985**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **PBFA II, A 100 TW Pulsed Power Driver For The Inertial Confinement Fusion Program**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Sandia National Laboratories Albuquerque, NM, 87185**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. Held in San Francisco, CA on 16-21 June 2013. U.S. Government or Federal Purpose Rights License.

14. ABSTRACT
The 100 TW Particle Beam Fusion Accelerator (PBFA II) is well into the procurement and assembly phases, with the first shot scheduled for January 1986. Installation of several major sub-assemblies is underway. The PBFA II output will drive a fast opening switch in the vacuum insulator stack, providing a 30 MV, 15 ns output pulse,which accelerates lithium ions. The ions will focus onto a pellet containing deuterium-tritium, producing fusion energy. Several research areas will be reviewed: low jitter, highly reliable 370 kJ Marx generators; highly synchronized gas switching at 5 MV; efficient water switch operation of 5 MV lines; series-parallel arrangements for increasing voltage or current; and plasma erosion opening switches.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

3. Maintain as much flexibility as possible in the machine to maximize adaptability to changing ICF requirements. The voltage conditioning section of PBFA II has been designed to allow voltage adding in various combinations of series-parallel line connections providing output voltages from 2 to 30 MV. The baseline configuration will have a center-tapped 14 MV output.
4. Minimize technical risk by testing a prototype module prior to procurement of the complete machine. The prototype experiment, called Demon, has been used to develop and proof-test all modular pulsed power components. The connection of the individual modules was tested in a one-fifth scale model, closely approximating the line interactions around the vacuum insulator stack.
5. Factor in operational considerations at all stages. Access, maintainability, ease of adjustment, and interchangeability are all important to the ultimate success of the machine as it goes into operation.

There may of course be conflicts between these design goals. Coordination, management, and conflict resolution are provided by the Central Project Office.[3] A technical staff for the PBFA II design project has been created from functional engineering and research organizations within Sandia's Pulsed Power Directorate. Approximately fifty engineers and scientists are now assigned to this project.

III. The PBFA II Accelerator

A. Marx Generators

An artist's drawing of PBFA II is shown in Fig. 1. The energy storage section stores 14 MJ of energy in 36 Marx generators.[4] Each Marx is bipolarly charged to 95 kV, with an erected output voltage of 5.7 MV. Each Marx is composed of sixty 1.35 microfarad capacitors with a combined stored energy of 370 KJ. The output from each Marx is connected through a single-pole, double-throw transfer switch to the intermediate storage capacitor, which is the first stage of pulse compression in the water section. The transfer switch is initially set to a liquid resistor dump load until the Marx is fully charged. To fire downline, the transfer switch is rotated to the intermediate store position using pneumatic actuators. The erected Marx capacitance is 22 nF, and the capacitance of the intermediate storage capacitor is 17 nF. The inductance of each Marx and transfer switch is 13 μH. The time to peak voltage of the ringing waveform is 1150 ns, and the ringing gain is near 1.0. The Marx dump resistor is also used as a late-time energy diverter to protect the Marx and intermediate store from ringovers caused by possible gas switch failure. A simple oil breakdown switch is used to connect the dump resistor into the Marx output some 400 ns after normal operation of the gas switch. A photograph of the PBFA II Marx is shown in Figure 2.

Switching in the PBFA II Marx is accomplished with SF_6 spark gaps, which are triggered by mid-plane field-enhanced electrodes. The triggering layout[5] is shown in Figure 3. The first six gaps in row 1 are triggered by an externally applied voltage pulse of about 500 kV amplitude and 80 ns risetime. The other gaps are sequentially triggered from the voltage pulses from the forward-feeding trigger resistors. Great care was taken to design this Marx for minimum timing jitter. A detailed computer circuit model of the trigger system was developed in conjunction with experimental data to understand and tune the erection sequence.[5] Figure 4 shows a plot of timing jitter (one standard deviation) versus gas pressure. The jitter at 36 psia is about 4 ns. At this pressure, the probability of a Marx prefire is lower than 1%.

Extensive effort was also directed toward defining and developing a reliable, low-jitter trigger source for the Marx array. This system consists of a single, nine-output, 100 kV, 10 ns risetime trigger generator and nine bipolar-charged Marx trigger generators (MTG). Each MTG, when triggered by the 100 kV input pulse, erects in a 540 kV, 80 nsec risetime pulse to fire four adjacent Marxes. The first-to-last spread of this system is expected to be less than 10 ns. When combined with the anticipated jitter and spread of the Marxes, the total spread into the water section of PBFA II is expected to be less than 35 ns.

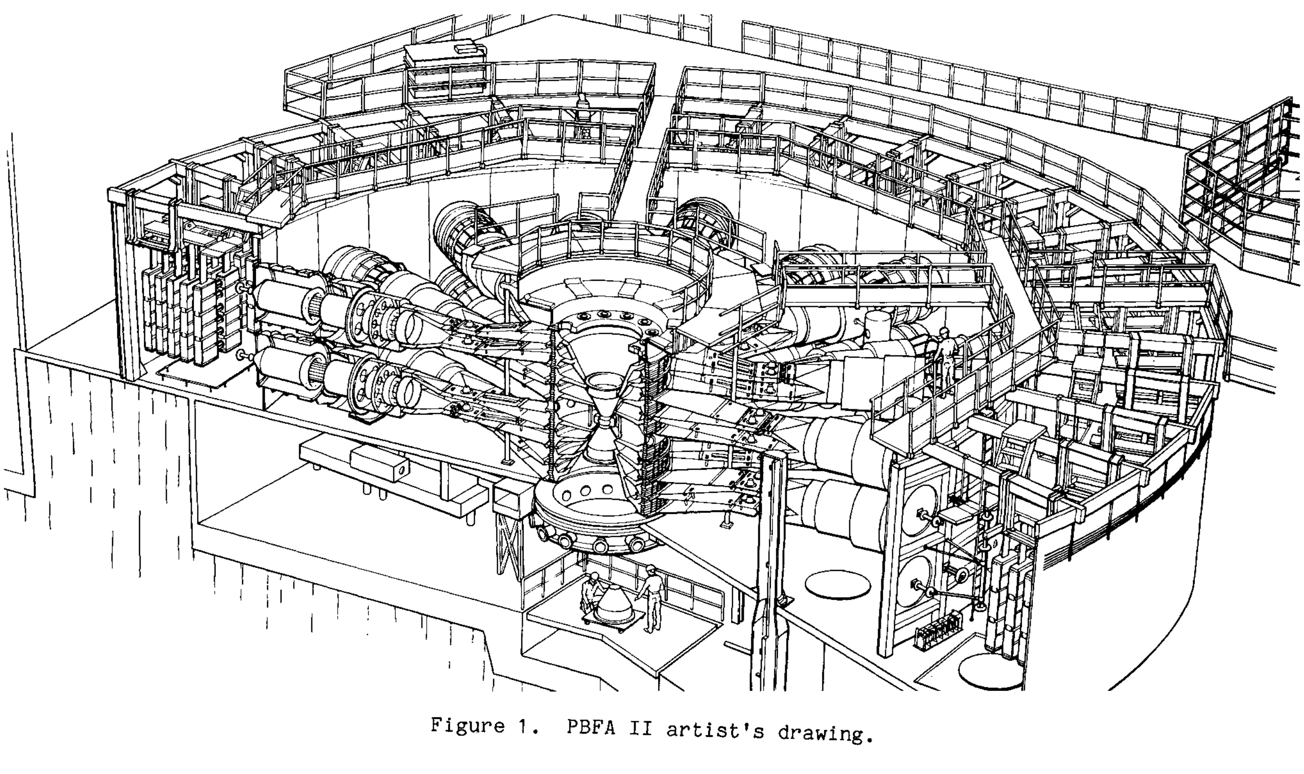

Figure 1. PBFA II artist's drawing.

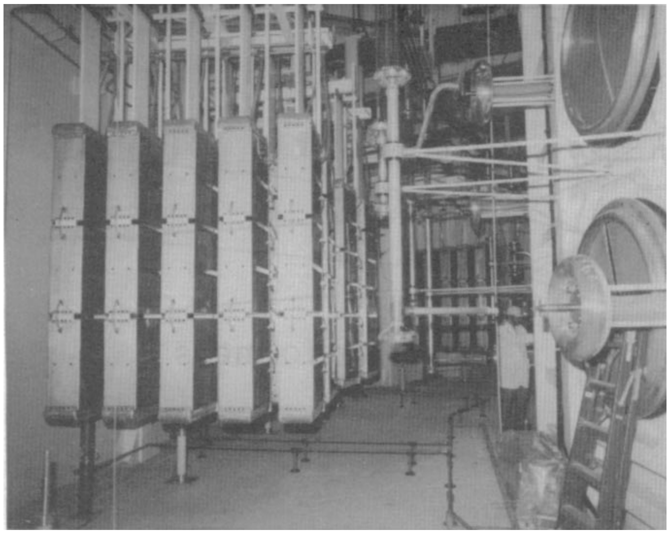

Figure 2. The PBFA II Marx generator.

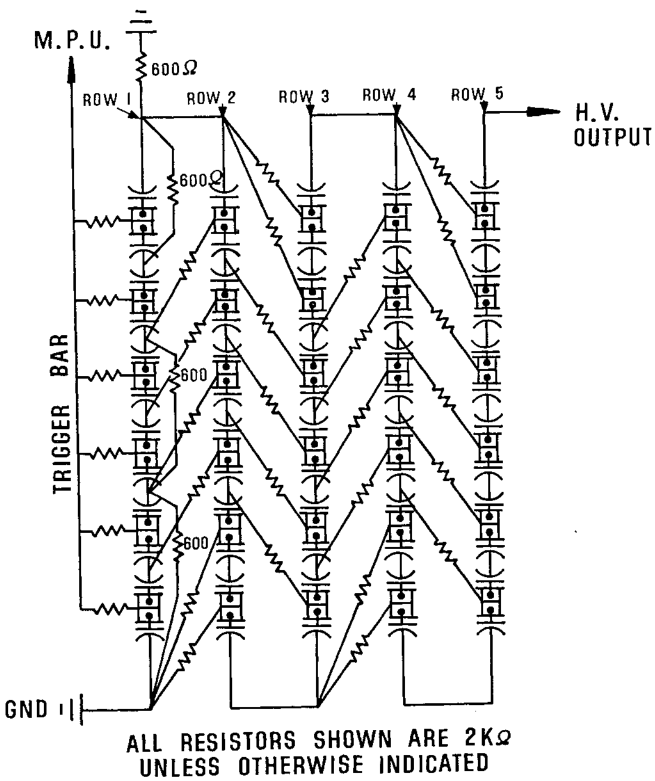

Figure 3. Marx trigger scheme.

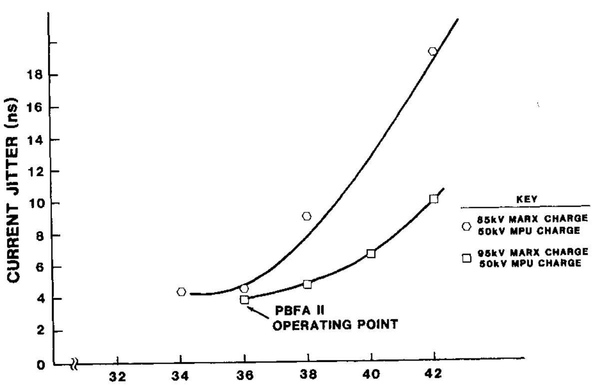

Figure 4. Marx jitter statistics.

B. Laser-Triggered Gas Switch

Module synchronization is a very important issue for PBFA II. The gas switch at the end of the intermediate storage capacitor serves both as a switch to charge the pulse-forming lines and also as the module timing control point that determines synchronization. The switch is insulated with SF_6 at a pressure of approximately 50 psia and will be triggered with a KrF laser.[6] To reduce the laser energy needed to trigger the 6 MV switch, a multi-staged design is employed in which 16 short gaps divide the applied voltage and uniformly grade the fields across the switch.[7] This switch, called Rimfire because the breakdown arcs occur at the rim of the disk electrodes, is shown in Figure 5. The trigger section is the largest gap on the right hand side of the drawing. A 20 ns, 25 mJ KrF laser pulse is applied to this gap to begin the breakdown process. This trigger gap has about 22% of the total voltage of the switch. About 5 ns after firing the laser, the trigger gap is bridged by an arc, and an overvoltage pulse propagates to the adjacent gaps. Each of these gaps are closed sequentially by the overvoltage, and the entire switch is closed after some 20 ns. With 25 mJ laser energy, the switch jitter is less than 1 ns, and at 10 mJ the jitter is 1.5 ns.

PBFA II will have one central KrF laser to trigger all 36 switches.[8] After allowing for losses, about 3 J of laser energy will be required. This laser, developed by Helionetics, is now undergoing tests. The 3 J beam will be subdivided into 36 beamlets by two splitting operations. First, the main beam is divided into 9 beams, each directed under the floor of the accelerator tank and into a vertical column that penetrates the floor of the tank and rises between four modules into the water section. Each of these beams is again split into four beamlets, with each directed into one of the pulsed power modules. Each beamlet then travels across the high voltage region of line 1 in the pulse-forming section, travelling along the center of an insulating tube, as shown in Figure 6. The 25 mJ beamlet is then focused near the center of the trigger gap in the switch. Adjustable position mirrors are used to equalize the propagation time of each beam.

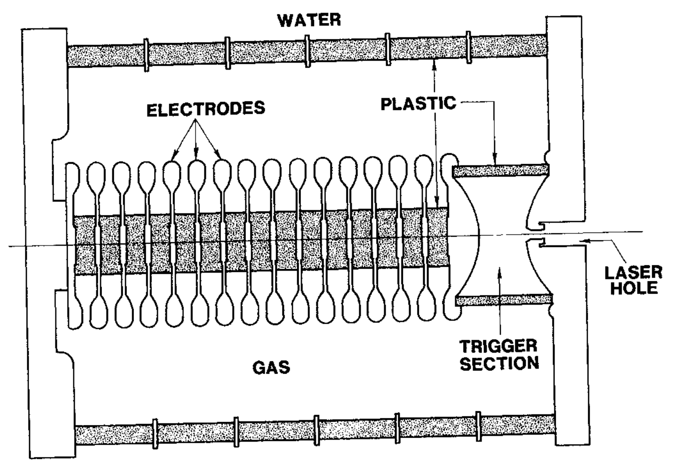

Figure 5. Gas switch schematic.

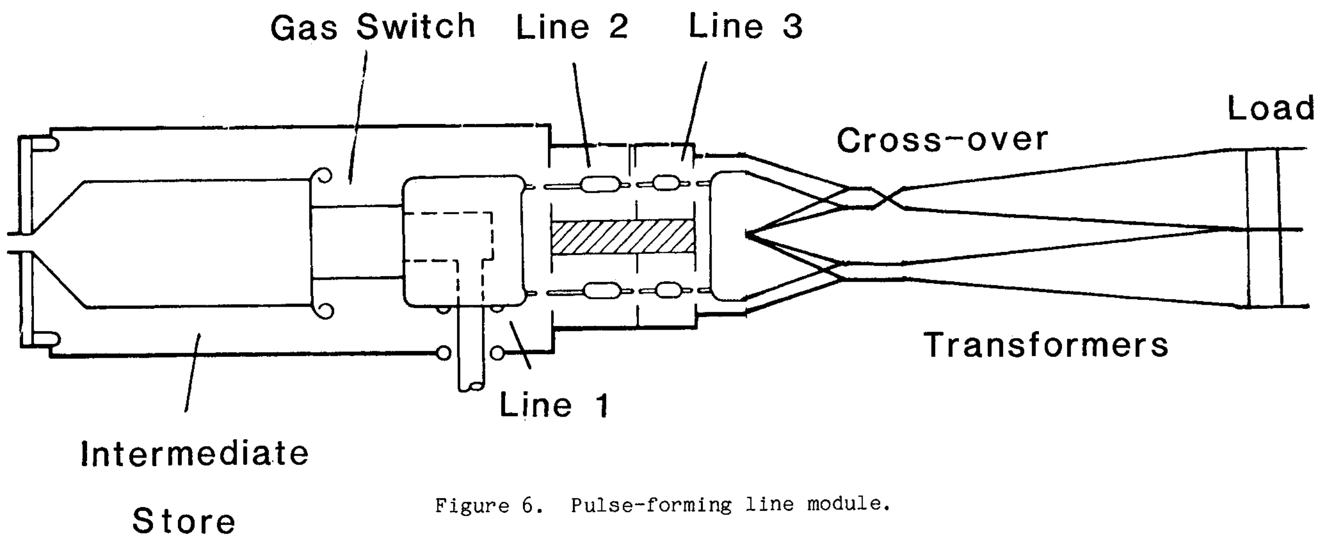

Figure 6. Pulse-forming line module.

C. Pulse-Forming Lines

A travelling wave charging technique, sometimes called "double-bounce," is used to charge the pulse-forming lines for PBFA II.[9,10,11] In this concept, the length of the line is comparable to the risetime of the charging pulse. Water self-break switches are used on the pulse-forming line output.[12] These switches are set to close after a few pulse transits across the line, but well before peak voltage.[11] With a travelling wave on the line, much of the energy is in the magnetic field at switching time; therefore, the peak switch voltage will be much lower than in a conventionally-charged line, where all the energy is in the electrostatic field. A shorter, lower inductance, lower jitter, lower loss water switch is the result.

Figure 6 shows the three pulse compression stages of the pulse-forming section. Typical water gap lengths for the switches are: line 1-2, 10 cm; line 2-3, 4 cm; and line 3, 0.5 cm. The third stage is used only for prepulse suppression, not to reduce pulse width. Figure 7 illustrates the travelling wave behavior during charging of lines 1 and 2, with representative waveform data from Demon. Electrical parameters of these sections are summarized in Table 1. Voltage monitors are located at the midpoint of each stage. The position of the charging wavefront is plotted at the bottom of Figure 7 to illustrate the process.

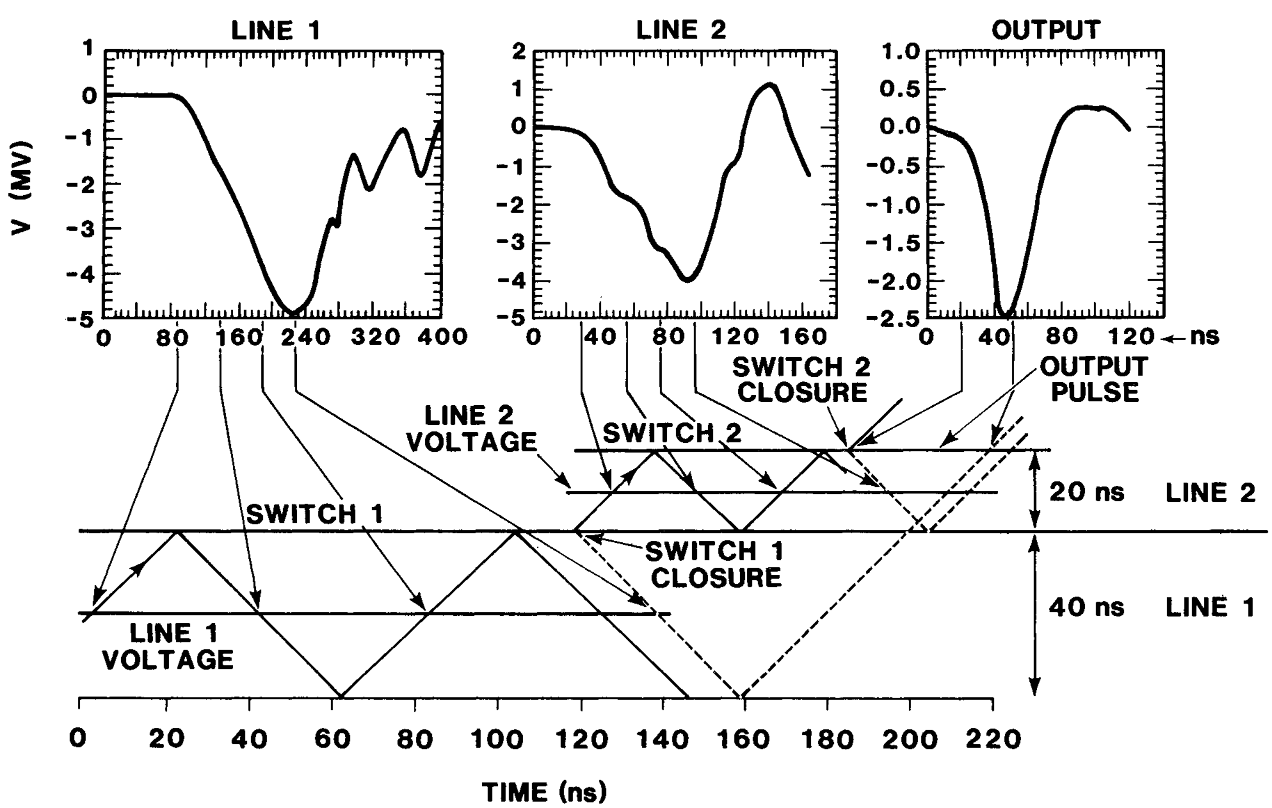

Figure 7. An illustration of the double-bounce charging technique for pulse compression.

Line 1 begins to charge at t=0, on the left-hand side of this figure. The wavefront reflects off the open water switch at the end of line 1 and travels back toward the gas switch. The wavefront is again reflected by the relatively high inductance of the gas switch and returns toward the water switch. The line 1 water switch closes after 100 ns on this shot, about 20 ns after the second-reflection arrival at the switch. Upon closure of the water switch, a charging wave is launched into line 2, where the process is repeated. A reversed-polarity discharge wave also is launched up-stream into line 1, and arrives back at line 2 after 80 ns. The arrival of the discharge wave marks the termination of line 2 charging. In this shot, the line 2 water switch closes after 40 ns, and an output pulse is then launched. The output pulse terminates when the discharge wave (dashed line in Figure 7) arrives at the output position.

The output pulse length can be adjusted by varying the closure times T_1 and T_2 of the line 1 and line 2 switches. If t_1 is the e-folding time of the line 1 water switch inductor, then the output pulse width t is[11]

$$t = 2T_1 - T_2 + 2t_1 .$$

The travelling wave charging technique requires wave reflections from discontinuities between stages; these reflections are never complete, and, therefore, some energy loss is to be expected. Table 2 summarizes energy efficiency measurements made on Demon.[11,13] The efficiency of the pulse-forming line, from the Marx generator to the coaxial output of line 3, is 46%.

D. Water Convolutes

The 36 individual pulsed power modules are connected together by disk convolutes, which are located at the vacuum insulator stack. To achieve a 14 MV input voltage to the vacuum load, the modules are added in a series-parallel arrangement (see Figure 1). Each module's output voltage is raised by a factor of approximately 2.8 by splitting the coaxial output into two flat plate transmission lines, inverting the polarity of one of these lines, feeding each line into a line transformer, and then adding the two output voltages for an output of 7 MV (see Figure 6). The machine is divided into four groups of nine modules each. These nine modules are connected in parallel by a disk feed at the vacuum insulator. The four groups are arranged to add voltage from the top and bottom of the machine toward the center, with a 14 MV accelerating potential.

This geometry allows a great deal of flexibility. The convolute and transformer geometry can be changed to give output voltages ranging from 2.5-28 MV. The baseline geometry, as described above, will have an output impedance of 2.2 ohms, with 14 MV positive potential at the center disk.

This convolute geometry uses open-sided transmission lines, with the potential for energy losses due to stray coupling to adjacent lines and the external environment. These coupling losses have been measured with two experiments: (1) a single-module transformer experiment on Demon[13] and (2) low voltage pulsing experiments of an 18-module scale model. The one-fifth scale model of the flat plate lines, transformers, vacuum insulator, and vacuum transmission lines was designed to reproduce the PBFA II geometry in as much detail as possible, and yet allow for configuration changes and accurate electrical measurements. Taking advantage of the symmetry plane through the mid-section of the PBFA II geometry, we were required to model only half of the machine. A single input pulse, of 12 ns half-width, was a close approximation to a scaled Demon pulse. This signal was split equally into 36 cables, which were connected to the individual transformer inputs. The forward-going voltage pulse in the flat-plate transmission line, just upstream of the transformers, and also the output current and voltage into a resistive load located at the center of the simulated vacuum transmission lines were measured. These measurements were used to derive Thevenin equivalent source impedance, open circuit voltage, and load inductance. The source impedance was 4.4 ohms for one-half of PBFA II or 2.2 ohms for the full machine. By comparison with actual high-voltage single-module data from Demon, the estimated forward-going output energy for PBFA II is 3.75 MJ.

Table 1
Pulse Compression Section Electrical Parameters

	C(nf)	Transit Time	Rise Time	Z	L
Inter-Store	16.4	65		4.6	
Gas Switch			50		400
Line 1	10.3	40		3.9	
Water Switch 1			16		100
Line 2	9.2	20		2.2	
Water Switch 2			11		50
Output				2.2	

Table 2
Energy Efficiency

	Energy	Net Efficiency
Marx	370	1.00
Intermediate Store	220	.59
Pulse-Forming Line Output	170	.46
Transition	155	.42
Cross-over	130	.35

E. Plasma Opening Switch

The final power compression stage is the plasma opening switch in the vacuum section.[14] The purpose of this switch is to store energy inductively in the magnetically-insulated transmission lines until peak current, and then rapidly open to transfer energy to the ion diode load, which is connected in parallel to the switch. The switch region extends over an annular region surrounding the ion diode, from 10 cm to 30 cm beyond the radius of the diode. The magnetically-insulated power feed is two-sided, and there is a switch across each of the sides. The switching element is a moderate-density plasma channel which is injected across the transmission line prior to the arrival of the power pulse. The plasma channel is initially conductive, with an estimated resistance of 2 milliohms. When the main power pulse arrives, the switch conducts a current of about 9 MA, storing energy inductively in the transmission lines. As the current rises, however, more ions are withdrawn from the plasma than are provided by the source, and a plasma sheath develops. As the switch opens, the magnetic field produced by current flowing downstream deflects electrons in the switch plasma back to the cathode, and the switch opening process is accelerated.[15]

As the plasma resistance rises, current is diverted into the 5.8 ohm parallel load ion diode. The time at which the switch begins to open is governed by the injected ion density. With proper adjustment of this parameter, the switch should substantially increase the voltage and power to the ion diode. The design goals for the plasma erosion opening switch are:

1. initial (or closed) impedance of 0.002 ohms,
2. conduct current for 60 ns before opening,
3. impedance risetime of 10 ns or less,
4. peak impedance of at least 50 ohms,
5. power pulse width (FWHM) of 15 ns,
6. voltage gain of 2,
7. power gain of 2,
8. azimuthal asymmetry of 1 ns or less.

This switch is now being developed in a series of experiments and analyses at Sandia and the Naval Research Laboratory,[15] providing scaling data at source voltages up to 2.2 MV and gaps up to 2 cm. PBFA II itself must be used for the final scaling experiments up to 30 MV and gaps of 6 cm. These experiments will be among the first to be fielded as the machine goes into operation.

F. Ion Diode

The goal of PBFA II is to produce a high intensity focused ion beam for ICF feasibility demonstration. Ion diode development will be the major thrust of the experiments after the machine becomes operational. An Applied-B ion diode will be the first diode fielded on the accelerator. This design has evolved from the PBFA I diode, which has achieved a power density of 1.5 TW/cm^2, at a source voltage of 1.8 MV, and an ion divergence of about 14 milliradians, using protons. PBFA II will use a high-purity lithium beam, accelerated to 30 MV potential, with a source power of over 150 TW. The PBFA I results were obtained at the same current density, diode radius, and total current of PBFA II. If the same ion divergence is assumed, then PBFA II power density calculations predict 80-120 TW/cm^2 at the focal point. But we expect smaller ion divergence for higher mass particles accelerated at higher voltage. If this more favorable divergence is in fact realized, focal intensity could be several hundred TW/cm^2.

IV. Present Status

As of June 1985, almost all of the support subsystems have been installed and checked out. These subsystems have met their design specifications and are ready to support accelerator subsystem testing.[16] All of the energy storage section has been assembled and is being tested. The Marx generators have all been certified individually at full charge voltage, firing into resistive loads. Charging and firing systems have been exercised. The pulse-forming section is now being assembled, and installation of the vacuum section of the machine will begin in the fall of this year. We have scheduled an accelerator readiness period beginning in December, 1985; the first full machine shot will be conducted before the end of January, 1986. The first period of operation will concentrate on optimization of the power flow characteristics of the machine itself. After this characterization and optimization phase, the machine will be dedicated to development and testing of ion diodes and ion focussing, leading to the ultimate ICF target experiments for which PBFA II has been designed.

References

1. J. P. VanDevender, J. A. Swegle, D. J. Johnson, K. W. Bieg, E. J. T. Burns, J. W. Poukey, P. A. Miller, J. N. Olsen, and G. Yonas, "Decreased Beam Divergence in Proof-of-Principle Experiment for the Light Ion Beam Fusion Facility, PBFA II," Lasers and Particle Beams, Vol. 3, pp. 93-105, 1985.

2. J. Maenchen, J. R. Woodworth, B. Foltz, E. J. T. Burns, D. Seidel, L. Dorrell, P. Johnson, P. Reyes, G. Torres, and G. Williams, "XUV Preionization Effects in High Power Magnetically Insulated Diodes," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

3. G. W. Barr, J. P. Furaus, and D. L. Cook, "A Status Report on the PBFA II Construction Project," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

4. J. Michael Wilson, "PBFA II Energy Storage Section Design," Proc. of the 4th IEEE Pulsed Power Conference, 1983, pp. 64-67.

5. L. X Schneider and G. J. Lockwood, "Engineering High Reliability, Low-Jitter Marx Generators," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

6. R. G. Adams, D. R. Humphreys, J. R. Woodworth, M. M. Dillon, D. Green, and J. F. Seamen, "Ultraviolet Laser Triggering of the 6 MV PBFA II Gas Switch," Proc. of the 16th IEEE Power Modulator Symposium, 1984, pp. 191-194.

7. D. R. Humphreys, K. J. Penn, J. S. Cap, R. G. Adams, J. F. Seamen, and B. N. Turman, "Rimfire: A Six Megavolt Laser-Triggered Gas Switch for PBFA II," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

8. R. A. Hamil, L. O. Seamons, R. A. Gerber, R. G. Adams, J. R. Woodworth, R. S. Blackburn, and W. C. Sweatt, "Laser-Trigger System Design for PBFA II," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

9. I. Smith, "Rapid Charging of Transmission Lines," Pulsed Sciences, Inc. Interim Report, Sandia National Laboratories, April 1981.

10. G. B. Frazier and S. R. Ashby, "Double-Bounce Switching," Proc. of the 4th IEEE Pulsed Power Conference, 1983, pp. 556-558.

11. B. N. Turman, J. F. Seamen, E. L. Neau, and D. R. Humphreys, "Development of the Pulse Compression Section for PBFA II," Proc. of the 16th IEEE Power Modulator Symposium, 1984, pp. 195-199.

12. J. D. Boyes and J. S. Cap, "Engineering Design for the PBFA II Pulse-Forming Section," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

13. E. L. Neau, B. N. Turman, J. F. Seamen, D. D. Bloomquist, S. R. Babcock, D. R. Humphreys, and L. X Schneider, "A Comparison of Energy Transport Measurements and Computer Simulations in a Single Module Prototype for PBFA II," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

14. D. H. McDaniel, R. W. Stinnett, and E. W. Gray, "Design and Optimization of the PBFA II Vacuum Interface and Transmission Lines for Light Ion Fusion," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

15. R. A. Meger, R. J. Commisso, G. Cooperstein, D. Hinshelwood, S. J. McDonald, P. F. Ottinger, T. J. Renk, S. J. Stephanakis, B. V. Weber, and F. C. Young, "Pulsed Power Application of the Plasma Erosion Opening Switch," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.

16. S. A. Goldstein, R. J. Clevenger, G. L. Donovan, G. T. Holman, R. R. Johnston, and D. R. Nations, "Important Concepts in the Assembly and Early Characterization of the PBFA II Accelerator," to be presented at the 5th IEEE Pulsed Power Conference, Arlington, VA, June 10-12, 1985.